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Original Article

EXPERIMENTAL INVESTIGATION AND ANALYSIS OF A MECHANICAL AND THERMAL PROPERTIES OF HYBRID POLYMER COMPOSITE PLATES

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ABSTRACT

The research and advancements in composite materials have gained an increased interest in twenty-first century due to the reduction of total weight and strength to weight ratio, thus requires the standardization of the main mechanical and thermal properties of a composite material. Hybrid composite materials are the superior for many application engineering materials. Hybrid compound stuff offers the designer to get the specified properties during a controlled goodly extent by the selection of fibers and matrix. The properties are tailored within the material by choosing completely different types of fiber incorporated within the same rosin matrix. In the present study, the mechanical properties such as tensile strength, flexure strength and thermal properties such as thermal conductivity and TGA have been investigated for the GFRP, CFRP, and Carbon and Glass fibers reinforced epoxy hybrid composite.

KEYWORDS: Composite Materials, Hybrid Composites, Flexure Test, DSC & TGA

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INTRODUCTION

Progresses within the field of materials science and technology have been born to those fascinating and rattling materials. A material [1] will give superior and distinct mechanical and physical properties as a result of it combine the foremost fascinating properties of its constituents whereas suppressing their least desirable properties. When considering high end engineering applications, composites are to be made lightweight and strong so as to improve the performance of the application [2]. The in-plane properties like tensile strength and stiffness of fiber reinforced composites are known to be high. But fiber reinforced composites perform poorly when under in plane compression or when through thickness properties are considered. At present, composite materials play a key role part business, industry and different engineering applications as they exhibit outstanding Strength to weight and modulus to weight magnitude relation since the application of composites spread into almost all engineering applications, it became a necessity to improve their thermo-mechanical properties. The properties of these composite materials can be further enhanced by integrating both CFRP and GFRP composites in a particular orientation and mixing ratio. Several fundamental constitutive relations have been developed throughout the later part of the 20th century, which helps in predicting the mechanical properties of the above mentioned materials. These relations can be of consequence to the composition of the material before its preparation. In the recent year considerable amount of research has been done on the composites for improvement in thermo-mechanical properties of the composites. The incorporation of the many differing kinds of fibers into one matrix has a crystal rectifier to the event of hybrid composites. The behavior of hybrid composites may be a weighed ads of the

individual elements among that, here's individual elements among that there is a further favorable balance between the inherent advantages and disadvantages. Also, using a hybrid composite that contains two or further styles of fiber, the advantages of one kind of fiber could compliment with what unit of measurement lacking among the choice. As a consequence, a balance in worth and performance is also achieved through correct material vogue. The properties of a hybrid composite chiefly depend upon the fiber content, length of individual fibers, orientation, extent of intermingling of fibers, fiber to matrix bonding and arrangement of every fiber. The strength of the hybrid composite is in addition dependent on the failure strain of individual fibers. Hybrid materials [3] square measure composites consisting of two constituents at the nanometer or molecular level the foremost common hybrid composites area unit a unit carbon-aramid bolstered epoxy that mixes mixes strength and impact resistance and glass-carbon reinforced epoxy that provides a strong material at an affordable price. Hybrid composite unit of measurement generally used once a combination of properties of varied types of fibers must be achieved or once longitudinal furthermore as lateral mechanical performances required. **N. Boumedienne et al. (2016) (4)** He worked on the elaboration and characterization of synthetic resin stuffed with gilded particle powder (aluminum, tin and zinc) composites. The scanning microscopy (SEM) footage, density measurements and diffraction analysis (DRX) showed a homogenous part of obtaining composites. The differential scanning measuring instrument unconcealed an honest adherence at matrix-filler interfaces, confirming the SEM observations. The measured glass transition temperatures rely upon composite fillers' nature. **R. Y. Yee et al (1994) (5**) He expressed a replacement technique that has been developed to measure the fiber content of number six fiber-reinforced substance polymer matrix composites. This new technique desires less material and fewer times than the standard matrix digestion technique. With information for the densities of the matrix, fiber, and composite, the strategy is also used to calculate fiber and void volumes. The new technique was verified by scrutiny results with those obtained by practice the standard matrix digestion technique. **Maya Jacob John** et al (2009 **(5)** aforementioned that the incorporation of the many different types of fibers into one matrix has diode to the event of hybrid bio-composites. The behavior of hybrid composites is also a weighted total of the individual elements throughout that there is an extra favorable balance between the inherent blessings and drawbacks. Also, using a hybrid composite that contains 2 or extra varieties of fiber, the advantages of 1 quite fiber may complement with what unit lacking at intervals the choice. As a consequence, a balance in worth and performance is also achieved through correct material vogue. The properties of a hybrid composite primarily rely on the fiber content, length of individual fibers, orientation, extent of intermingling of fibers, fiber to matrix bonding and arrangement of every the fibers. The strength of the hybrid composite is in addition, enthusiastic about the failure strain of individual fibers. This chapter focuses on the varied varieties of hybrid composites. The thought-about developing with of hybrid composites leads to an honest balance of properties. **WangY [6**] Hybrid composites measure smart potential for engineering material in many applications. The hybrid compound material offers the designer to urge the required properties throughout a controlled extended extent by the choice of fibers and matrix. The properties square measure tailored at intervals the fabric by choosing completely different types of fiber incorporated at intervals constant organic compound matrix at intervals the gift investigation, the mechanical properties of carbon and glass fibers strengthened epoxy hybrid composite were studied. The vacuum material technique was adopted for the fabrication of hybrid composites. The vital mechanical properties like hardness, permanency, tensile modulus, ductility, and peak load of the hybrid composites were determined as per ASTM standards. The mechanical properties were improved as a result of the fiber reinforcement content accumulated at intervals the matrix material. N**. K. Kucher [7]** studied the elastic deformation behavior of laminated epoxy composites reinforced with one-way carbon fibers and satin-woven glass material. The efficiency of various experimental procedures of

determination of averaged elastic characteristics of laminates is analyzed. The impact of decreasing the take a look at temperature to seventy seven K on the mechanical behavior of the above-mentioned materials is studied**. VijayaRamnath et al. [8]** studied the mechanical behavior of fiber and terminated that the polyester chemical compound composite shows higher shear strength and additionally the multiplied performance of stiffness and strength area unit glad at 12mm thick GFRP. **Jose David Ricardo Tarpani [9]**: Quasi-isotropic tensile properties of mechanical grade carbon-epoxy matter composite laminates, in every as-received and pre-fatigued state, were determined and compared. Two-dimensional woven forms broken catastrophically below identical cyclic loading conditions obligatory to the fiber style, thus this prevents their residual properties from being determined. **Kretsis [10**], used a hybrid product of glass-carbon fibers, used unifacial material for the mechanical properties of the hybrid composite. The tensile modulus of hybrid composites was obtained using the rule of mixtures, whereas classical laminate theory was accustomed verify the flexural modulus low cost estimates for the other elastic properties were obtained from the rule of mixtures. In tensile tests of hybrids, the failure stress of the low elongation constituent material was raised the development of the expected primary failure strain was larger for smaller proportions and concentrations of the low-elongation material. Whereas the compression and flexure failure was undetermined. **Murugan et al. [11]**, used glass/carbon hybrid composite that had a pair of symmetrical four stratified glass/carbon hybrid laminates and a pair of dedicated four stratified glass or carbon laminates that were won by one exploitation the hand shot and compression molding techniques. It had been found static mechanical properties like sturdiness, flexural strength and impact strength and dynamic mechanical properties adore storage modulus, loss modulus and loss issue. The modulus curves of dedicated and hybrid composite laminates in an exceedingly Cole-Cole plot that showed Associate in nursing imperfect semi circular curve indicating the non-uniformity of the laminates and had comparatively good fiber/matrix bonding. **Elanchezhian et al. [12],** Worked with the fabrication and investigation of fiber composites and compares it with GFRP and CFRP used severally. Mechanical behavior of the composite was obtained by testing the composite laminates for tensile (at variable strain rates and temperatures), flexural (at variable strain rates) and impact. The composite is factory-made by hand shot methodology. It completely was found that the CFRP composite had higher properties than the GFRP in tensile and flexural.

From literature, there are only a few numbers of studies regarding woven fabric as well as unidirectional fabric type hybrid composite. Therefore, research on hybrid composite that is fabricated by different type of fiber and same orientation. In order to give better suggestions to the manufacturer for selecting the appropriate material used in different applications. The purpose of this study is to investigate and compare the effect of the fiber on same fiber orientation and mechanical behaviors of carbon-glass hybrid composites.

Problem Description

From the review on the previous literatures, it has been found that the literatures on carbon-glass fabric hybrid composites are rarely reported. Aim of the study is to have a comparative study of individual glass fabric reinforced epoxy composite, carbon fabric reinforced epoxy composite with glass-carbon reinforced epoxy hybrid composites. The key objectives of the work are:

- To fabricate Glass, Carbon and Hybrid Fiber Reinforced laminated composite using compression molding technique as per requirements.
- To find the tensile and inter laminar behavior of laminates using Tensile and SSB tests.

- To investigate the hardness strength of a laminate composites.
- To find the critical buckling load of a composite plates.
- And finally compare the all results with respect to the fiber, and to justify the best composite material among GFRP/CFRP/HFR
- Thermal stability of the sample can be found out through Thermo gravimetric Analysis (TGA).
- Determining the heat conductance of the sample by using Differential scanning calorimeter.

EXPERIMENTS

Materials and Fabrication Methods

The resin system was used in this study is a bi-functional epoxy system where, the epoxy resin of Lapox L12 (DGBEA), the hardener K6 were mixing ratio of 10:1 ratio resin and hardener respectively supplied by the Ciba, India. The unidirectional glass fiber fabric was manufactured by Interglas Technologies; Germany having 220 gsm and carbon fiber of 230 gsm was supplied by the Suntech fibers, Bangalore, as shown in Figure

Composite Laminates Preparation and Sample Configuration

The Glass fiber and the Carbon fiber laminates having epoxy resin as the matrix material were prepared using the hand-layup method. The Glass and Carbon fiber mats were hand laid-up using epoxy matrix as a binder which contained the mixture of epoxy resin and hardener in the ratio of 10:1. Total six laminates were prepared with the configuration in which GFRP laminate plates are two, CFRP plates are two and Glass-Carbon hybrid plates are two. The laminates were made using the compression molding machine and covering plastic was used on the outer surface of the laminate so the epoxy matrix would not stick to the metal plates of the compression molding machine and it also provided smooth and even outer surface. The orientation we followed to make GFRP and CFRP composite listed below table.

Table 1: Orientation of Composite Layers

Layer Number	Orientation (Degrees)
1	0
2	45
3	90
4	-45
5	-45
6	90
7	45
8	0

And Glass-Carbon reinforced epoxy hybrid composite has listed below table

Table 2: Orientation of Hybrid Composite

Layer Number	Orientation (Degrees)	Fabric Type
1	0^0	Carbon
2	45^0	Glass
3	90^0	Carbon
4	-45^0	Glass
5	-45^0	Glass
6	90^0	Carbon
7	45^0	Glass
8	0^0	Carbon

Sample Characterization

ASTM D3171 standard was used for burn-off tests, which are to see the fiber volume fraction of the composites. Five specimens of 25mm x 25mm were ready from totally different made-up laminate panels. The density of specimen was measured by densitometer. The samples were then placed within the heat up Nabertherm heat treatment machine and maintained at 500˚C for 5 hours. When the resins are absolutely burn, the remaining weights of fiber reinforcements in its melting pot were measured. Once all the info is measured, the volume fraction was calculated using Eq. 1.

$V_{f} = (M_f/M_c)\ x100x\ (\rho_{c/}\,\rho_f)$

Where:

V_f = volume percent of reinforcement in the specimen M_f =final mass of specimen after combustion ,

M_c =initial mass of specimen after combustion

ρc = density of the composite specimen

On the other hand tensile test, flexure test and hardness test has conducted to find mechanical properties of a composite and also along with DSC and TGA has done to determine thermal conductivity and thermogravity analysis of a composite.

Tensile Test

The objective of this test is to estimate the ultimate strength, young's modulus and strain to failure of the laminated composite. The specimen is made according to ASTM D3039 specimen specifications. Shimadzu Universal Testing Machine (UTM) with loading rate of 2 mm/min was used.

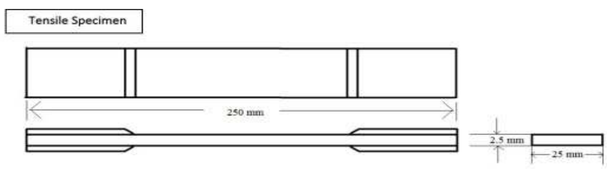

Figure 1: Testing Specimen of Tensile Test

SHORT BEAM SHEAR (SBS)

The SBS test is used to determine interlaminar shear strength of the laminates. The data hence obtained can be used for studies related to strength or for comparing different type of composite materials. The specimen was made following ASTM D 790-2003specification. This specification suggests that the width of the laminate should be twice its 45 thickness while the length should be six times the thickness. Accordingly, the specimen was made to the dimension of 8mm*16mm*48mm

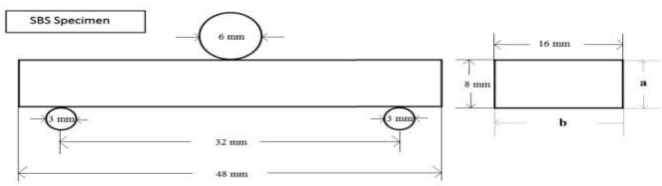

Figure 2: Testing Specimen of Short Beam Shear

Hardness Testing

The Rockwell hardness test method, as defined in ASTM D 2240:2003, is the used hardness test method. The Rockwell test is generally easier to perform, and more accurate than other types of hardness testing methods.

Figure 3: Hardness Testing Machine

Differential Scanning Calorimetry (DSC)

Differential scanning calorimetry, or DSC, is a thermo-analytical technique in which difference in the amount of heat required to increase the temperature of a sample and reference is measured as a function of temperature. Both the sample and reference are maintained at nearly the same temperature throughout the experiment. Generally, the temperature program for a DSC analysis is designed such that the sample holder temperature increases linearly as a function of time.

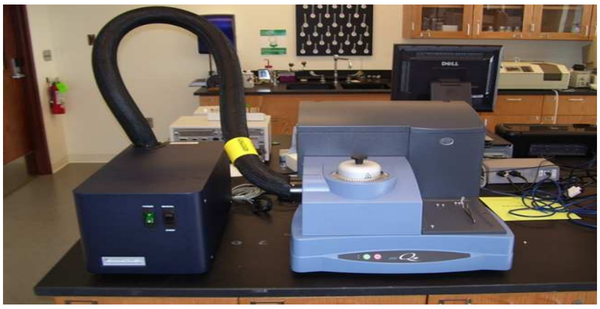

Figure 4: A Working DSC Setup

Thermo Gravimetric Analysis (TGA)

Thermo gravimetric analysis or thermal gravimetric analysis (TGA) is a method of thermal analysis in which changes in physical and chemical properties of materials are measured as a function of increasing temperature (with constant heating rate), or as a function of time (with constant temperature and constant mass loss). TGA can provide information about physical phenomena, such as second-order phase transitions, including vaporization, sublimation, and absorption and desorption.

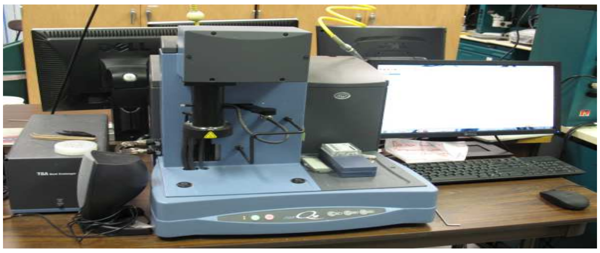

Figure 5: A Working TGA Setup

RESULTS AND DISCUSSIONS

Fiber Volume Fraction

To ensure the quality consistencies of each specimen before conducting the experiment were determined both volume fraction and density of a fabricated laminate. For GFRP density was nearly having 1.84g/cm2 at the same time for CFRP was having 1.6 g/cm2 and for Hybrid composite having 1.75 g/cm2. Whereas volume fraction of GFRP was 54%, CFRP 58% and for hybrid composite is nearly 57%.

Tensile Properties

The results of tensile properties data for GFRP, CFRP and hybrid composite have been summarized in Table 3 As expected, hybrid composites laminates showed the highest value of tensile strength and modulus properties compared with the other two laminate composites. The value of ultimate strength for hybrid composite is 141.83 N/MM2 which is higher than CFRP and GFRP composite. But the strength of CFRP laminate is one and half fold increment than GFRP. The presence of carbon fibers has restricted the crack propagation in the laminate; hence allow the hybrid composites to attain their higher ultimate tensile strength.

Table 3: Tensile Test Results

S. No	Sample Description	Ultimate Load	Ultimate Strength
1	GFRP	6.600KN	141.83N/MM^2
2	CFRP	8.940KN	208.246
3	Hybrid Composite	10.140KN	217.084

Flexure Properties

The ultimate goal of the test is to find the interlaminar shear strength of the laminates. The device used for finding the flexural strength is Universal Testing Machine (UTM). The test results are as follows:

- The glass fiber has a flexural strength of 342.61N/mm^2
- The carbon fiber is estimated to have a flexural strength of 414.22N/mm^2. This material is noted to have the highest strength amongst all the three composites.
- Hybrid composites are calculated to have a flexural strength of 388.19 N/mm^2.

Table 4: Flexural Test Results

Sl No	Composite	Load	Flexural Strength
1	Glass fiber	2240	342.61
2	Carbon fiber	2740	414.22
3	Hybrid composite	2620	380.19

Hardness

In this test, the hardness properties of the materials are calculated. The testing device used here is shore hardness tester. The sample testing composites used here are glass fiber, carbon fiber and hybrid composites. The hardness test is conducted thrice to obtain a precise value. The test results for the above-mentioned composites are as follows:

- The hardness for glass fiber is found as 56, 57, and 57 respectively during a 3-time testing process.

- The hardness for carbon fiber is found as 59, 58, and 59 respectively. The maximum level of hardness is found in glass fiber when compared to that of the remaining composites in this test.
- The hardness for hybrid composites is indicated as 57, 57, and 58 respectively.

Table 5: Hardness Test Results

S. No	Sample Description	Shore “D” Hardness
1	Glass fiber	56,57,58
2	Carbon fiber	59,58,59
3	Hybrid fiber	57,57,58

Differential Scanning Calorimetric (DSC)

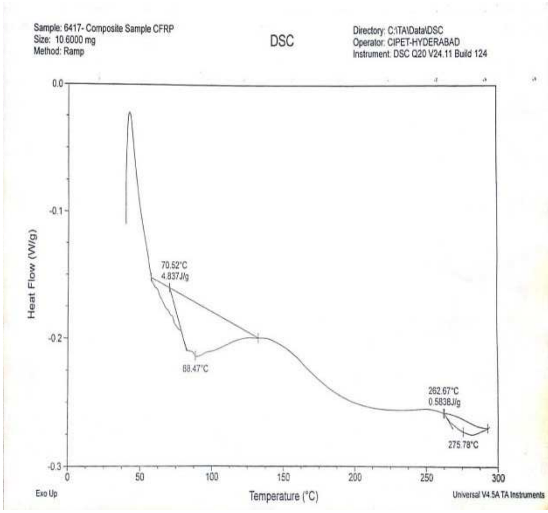

Figure 6: DSC Results for CFRP

As shown in the Figure 6, there are some transitions that took place in carbon fiber composite during differential scanning calorimetry. So, coming to the graph, it has exhibited an exothermic property by conducting heat through it up to a temperature of 440C and from that point there has been a decrease in conduction of heat through it and the change is varied linearly with a negative slope indicating the endothermic reaction in which the material absorbs the heat flowing through it and which is responsible for the decrease in the conduction of heat energy. From 440C to 70.520C the conduction has fallen to a value of 4.837J/g. there is a further decrease in heat conduction from 70.520C to 88.470C but the graph has some disturbances in its path so that the graph is not linear in this particular case due to a transition. After that transition, the heat conduction again increased up to a temperature of 1350C approximately and from there the conductance has again decreased and reached a value of 0.5838J/g at a temperature of 262.670C. This is the variation of heat conduction in carbon fiber composite through varying temperatures.

From the Figure 7, we can say there are many transitions in the composite at which there is a change in conduction of heat and it has not followed any trend in the graph. Starting from a point of room temperature

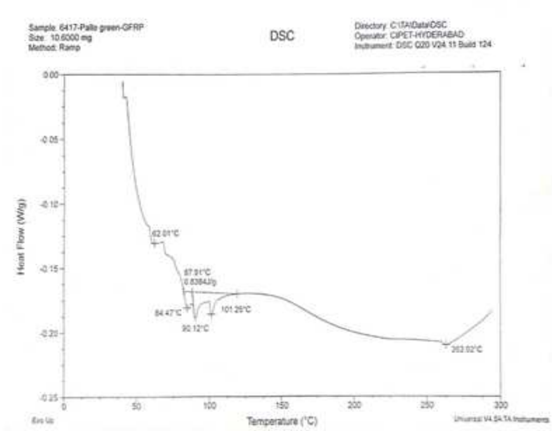

Figure 7: DSC Results for GFRP

(32oC), there is a gradual decrease in heat conductance up to 600C Starting from a point of room temperature (32oC), there is a gradual decrease in heat conductance up to 600C and again sudden fall from 600C to 62.010C. The material has exhibited three transitions in between 84.470C and 1120C. At which there are irregular deflections in heat conductance without following any trend. As the temperature increases from 1120C to 2630C there is a smooth negative curve representing the endothermic process in which, conduction is further decreased due to absorption of heat by the sample? After a certain temperature i.e. 263.020C there is an increase in conduction due to exothermic process in the sample.

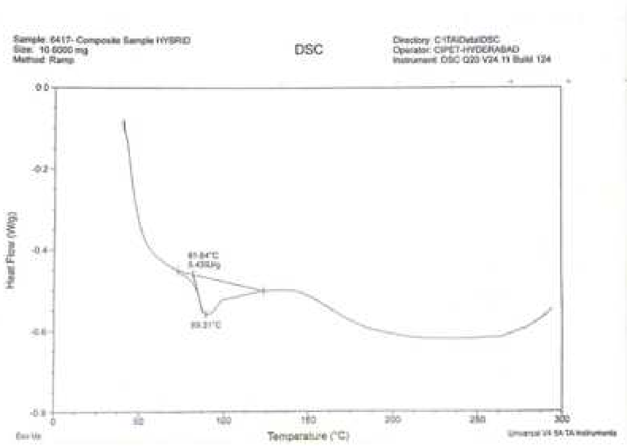

Figure 8: DSC Results for Hybrid Composite

The Figure 8 shows a regular trend in case of a hybrid material. The heat conductance has increased from a point of room temperature to 440C exhibiting exothermic reaction in which, heat is rejected or released by the sample. There is a smooth curve with negative slope indicating the endothermic process in which the heat is absorbed by the sample and due to this, the conduction decreased to a value of 5.439J/g till the sample reached a temperature of 81.640C and there is a transition of sample at 89.310C at which the sample reached a value of minimum conduction of heat. There is an increase in heat conductance from point of 89.310C to 1400C approximately and from that there is a gradual decrease in conduction and finally it has an increase in heat conductance reaching 2900C approximately.

Thermo Gravimetric Analyzer (TGA)

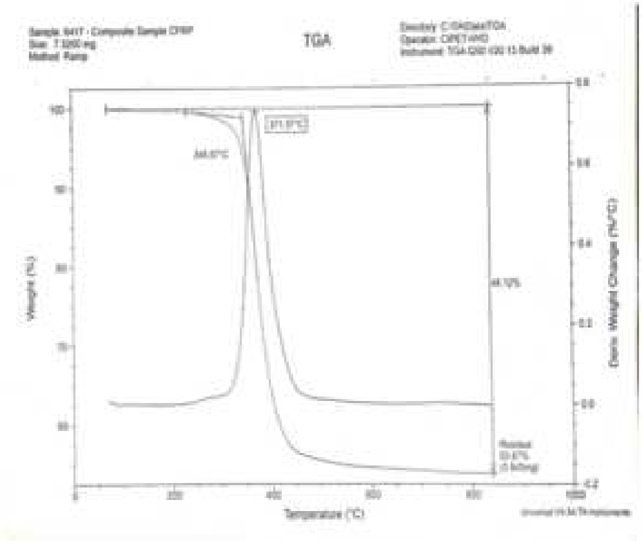

Figure 9: TGA Results of CFRP

Figure 9 shows, in this test, initially the sample has no change in its mass up to 1000C from room temperature. From 1000C it has deviated from its original mass and there is a slight decrease in its mass up to 2000C from where the slope of the graph has an increase in its slope negatively, which determines, an increase in the rate of change in mass up to 3200C, this decrease in mass up to this point denotes the evaporation of volatile substances from the sample. So, the sample has a low rate of mass change for a certain scale of temperature. From 3200C to 4500C there is a decrease in the mass of the sample drastically, which indicates the evaporation of resin and hardener mixture. But, still there is a further decrease in mass indicating the small traces of resin and hardener mixture which, attached to the fibers of the sample. The final amount of traces left over at 8500C is the amount of pure fiber present in the sample. The percentage of mass fiber in the whole sample is 53.87% indicating 3.943mg of fiber out of 7.32mg of total sample.

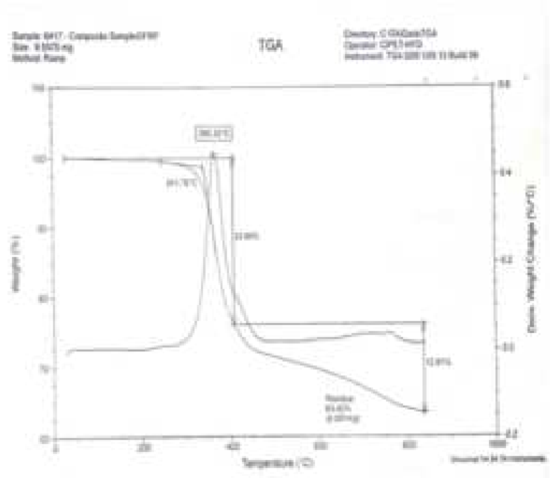

Figure 10: TGA Results of GFRP

Figure 10 shows, Initially, for the sample, the volatile particles have been evaporated up to 2800C approximately, up to which, the change in mass is very less when compared to that of the rest of the graph. From 3000C to 4000C the mass has decreased drastically, i.e. the percent of mass change is nearly 23.95% within a gap of 400C, indicating the

evaporation of resin and hardener content in the sample. The sample has further lost its mass up to 8500C gradually and the left over mass is known as the fiber content in the sample. The graph represents that the sample contains 63.42% of fiber content, i.e. 6.061mg of fiber out of 9.557gm of total sample weight.

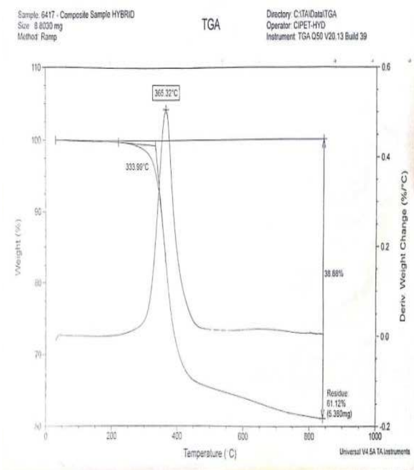

Figure 11: TGA Results of Hybrid Composite

Figure 11 shows, Same as both CFRP and GFRP, the Hybrid composite has lost its volatile substances up to 3000C from 2200C, similarly, the hardener and resin mixture in the sample has been undergone vaporization from 3000C to 4100C which is represented by a steep slope of the curve as shown by a tangent drawn normal to it at both the temperatures. The fiber content in the sample is 5.38mg out of 8.8030mg of total content, which constitutes a weight percent of 61.12 of the total sample

CONCLUSIONS

From the tests, it is found that volume fraction of fiber is occurring nearly more than 55% of composite. Among all the three composites that have undergone the tensile test, it is found that the hybrid composite material has maximum ultimate load and ultimate strength. It is calculated that carbon fiber has maximum hardness. From the test results of flexural strength, it is derived that carbon fiber has maximum strength. From the thermal tests, it is clear that no product is having thermal stability as they are changing

Their properties with respect to change in temperature. The fiber content is more in GFRP composite compared to CFRP and Hybrid fiber content. When coming to the transitions in DSC test, the hybrid composite has shown a good transition. GFRP composite has more number of transitions, it may be due to the fiber and epoxy resin combination. Anyway, the GFRP composite has a good heat conductor compared to both the composites , but the sample is not having stability as of CFRP and Hybrid composite samples.

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